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(54) **CONVERGING SUCTION LINE FOR COMPRESSOR**

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CPC ***F25B 41/40*** (2021.01); ***F04D 17/10*** (2013.01); ***F04D 29/4213*** (2013.01); ***F15D 1/04*** (2013.01);
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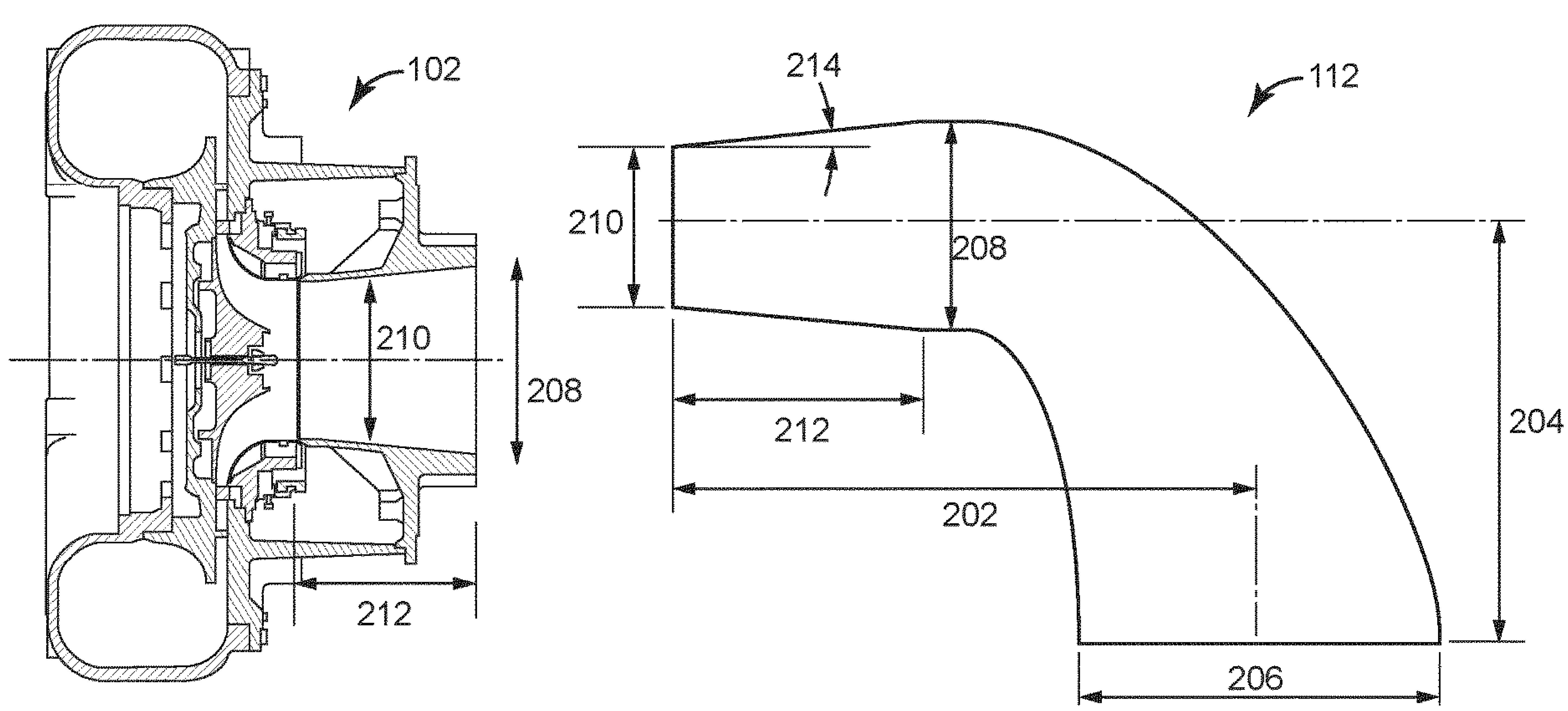
(57) **ABSTRACT**

A compressor includes an inlet and the inlet includes a flange and an impeller eye. The flange is connected to a suction line that transfers a refrigerant into the compressor via the impeller eye. The refrigerant flows into the compressor with an amount of swirl and a pressure loss. The suction line includes a geometry that includes a constantly decreasing cross-sectional area in a direction towards the compressor. The geometry of the suction line is configured to reduce the amount of swirl and the pressure loss.

17 Claims, 5 Drawing Sheets



(51) **Int. Cl.**

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F04D 17/10	(2006.01)
F04D 29/42	(2006.01)
F25B 1/053	(2006.01)
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(52) **U.S. Cl.**
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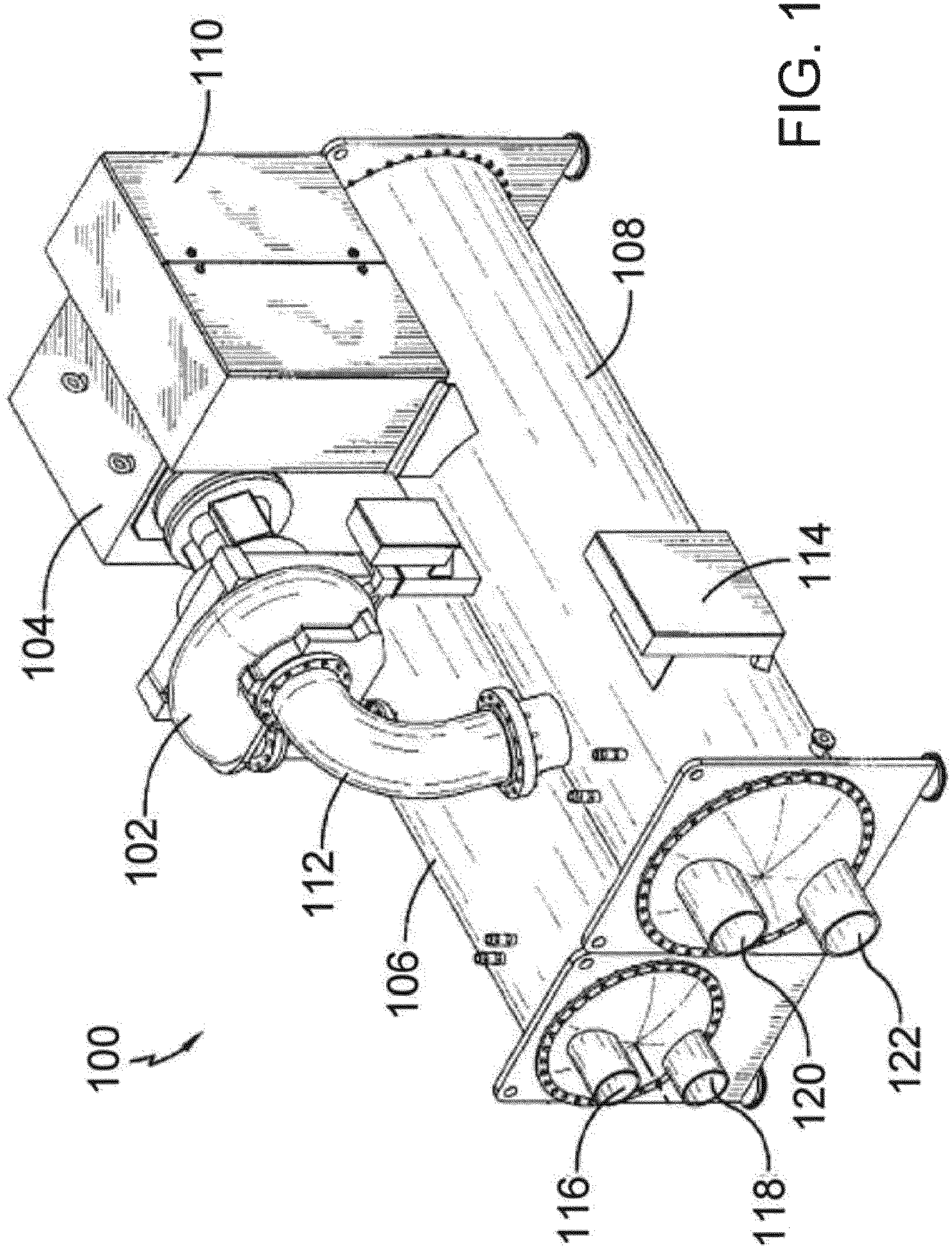

FIG. 1

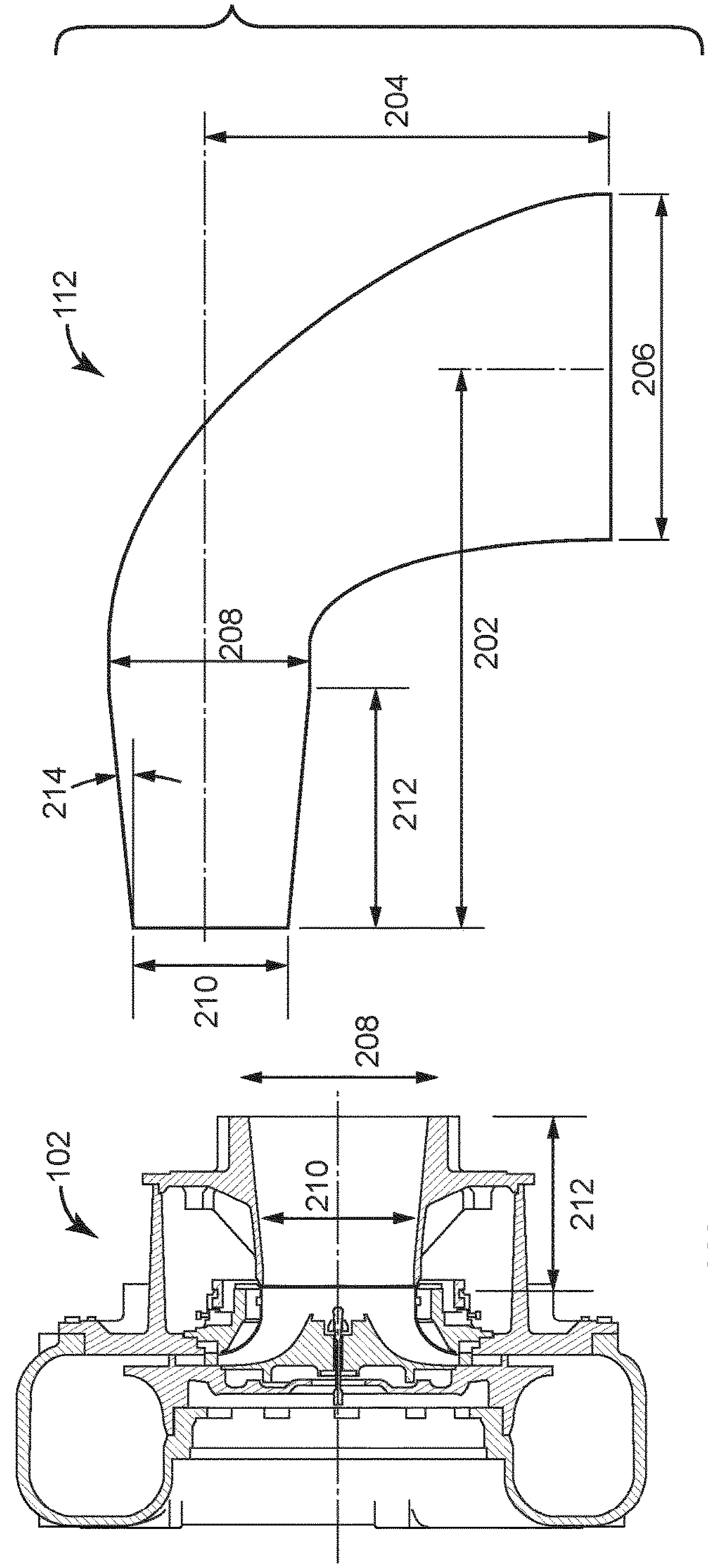

FIG. 2

300

	Capacity (Tons of Refrigeration)	300	450	520	630	750	880	1000	1200
202	Axial Length (in)	28.000	28.000	31.000	35.000	37.000	39.898	42.000	46.310
204	Height (in)	20.000	24.540	22.673	25.000	26.500	26.772	28.580	31.190
206	Evaporator Flange Diameter (in)	17.250	19.250	21.250	23.250	25.250	27.250	29.250	31.250
208	Compressor Flange Diameter (in)	10.000	12.000	13.250	15.250	17.250	17.250	19.250	21.210
210	Impeller Eye (in)	7.755	9.515	11.178	12.326	13.432	14.518	15.499	16.914
212	Compressor Inlet Axial Length (in)	12.000	13.727	13.000	15.400	15.500	12.000	17.000	19.173
214	Compressor Inlet Angle (deg)	5.344	5.172	4.556	5.423	7.021	4.837	6.296	6.451
216	Suction Line In/Out Diameter Ratio	1.73	1.60	1.60	1.52	1.46	1.58	1.52	1.47

FIG. 3

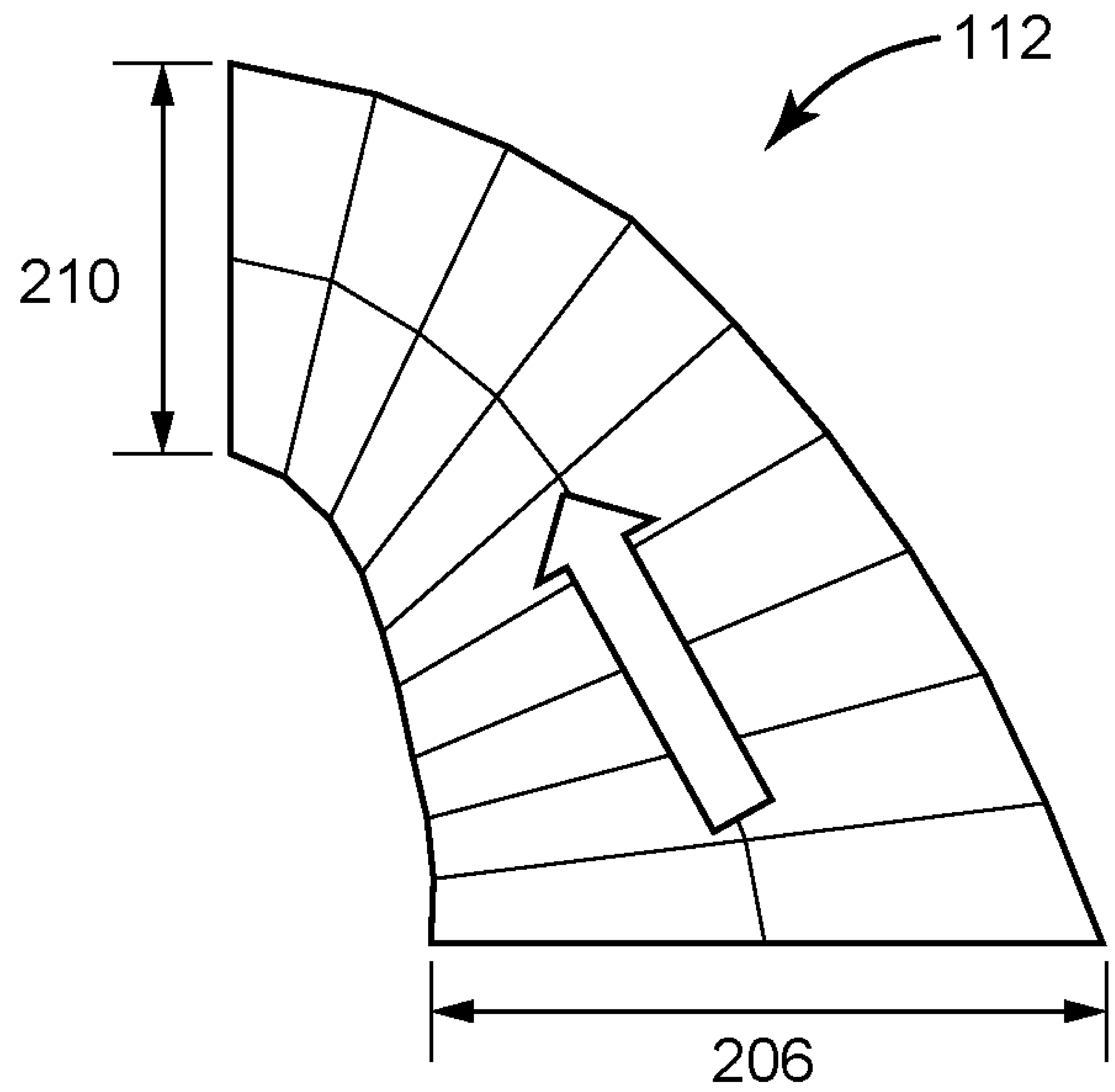
112
210
206

FIG. 4

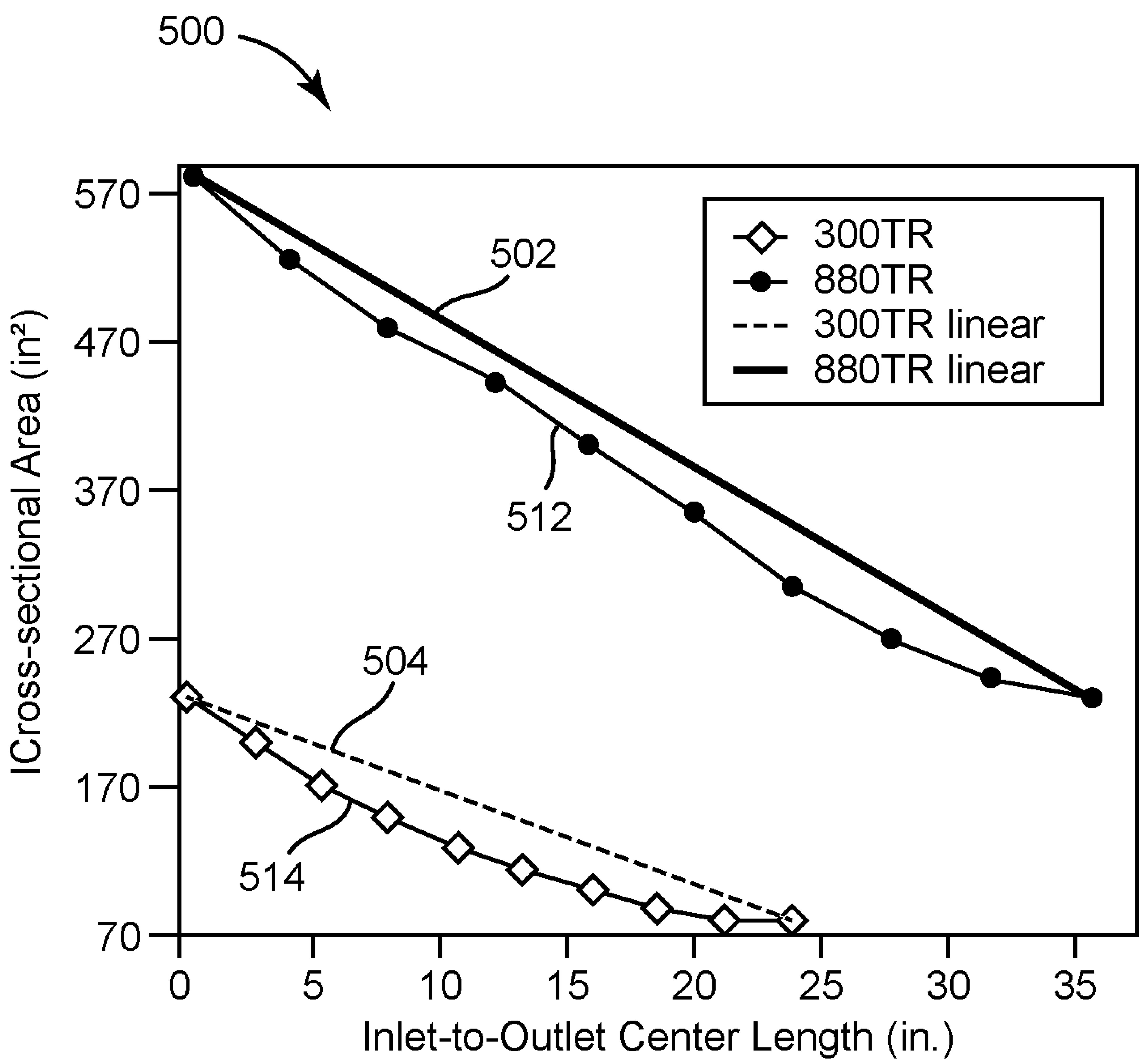
500
570
470
370
270
170
70
lCross-sectional Area (in²)
0
5
10
15
20
25
30
35
Inlet-to-Outlet Center Length (in.)
300TR
880TR
300TR linear
880TR linear
502
512
504
514

FIG. 5

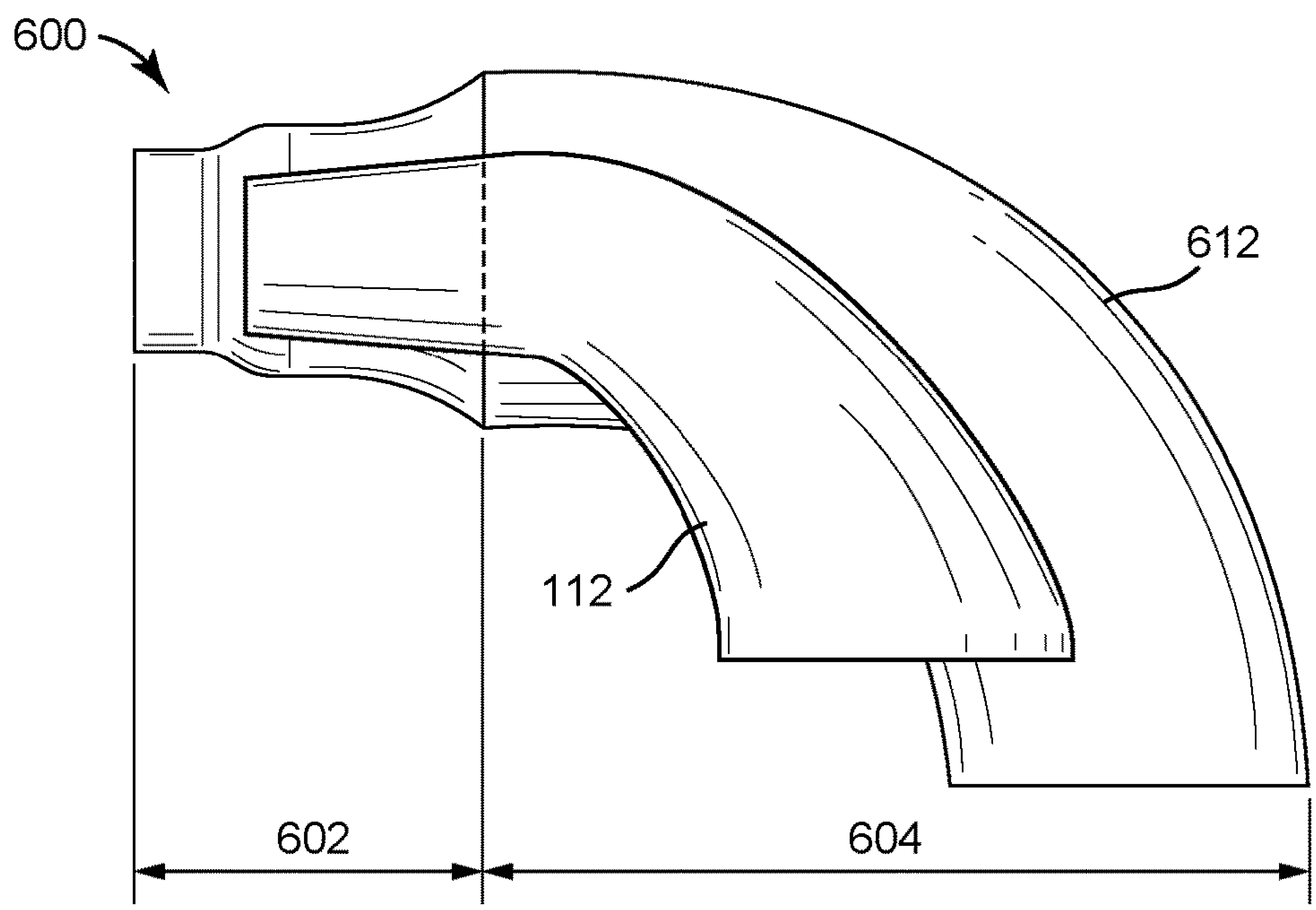

FIG. 6

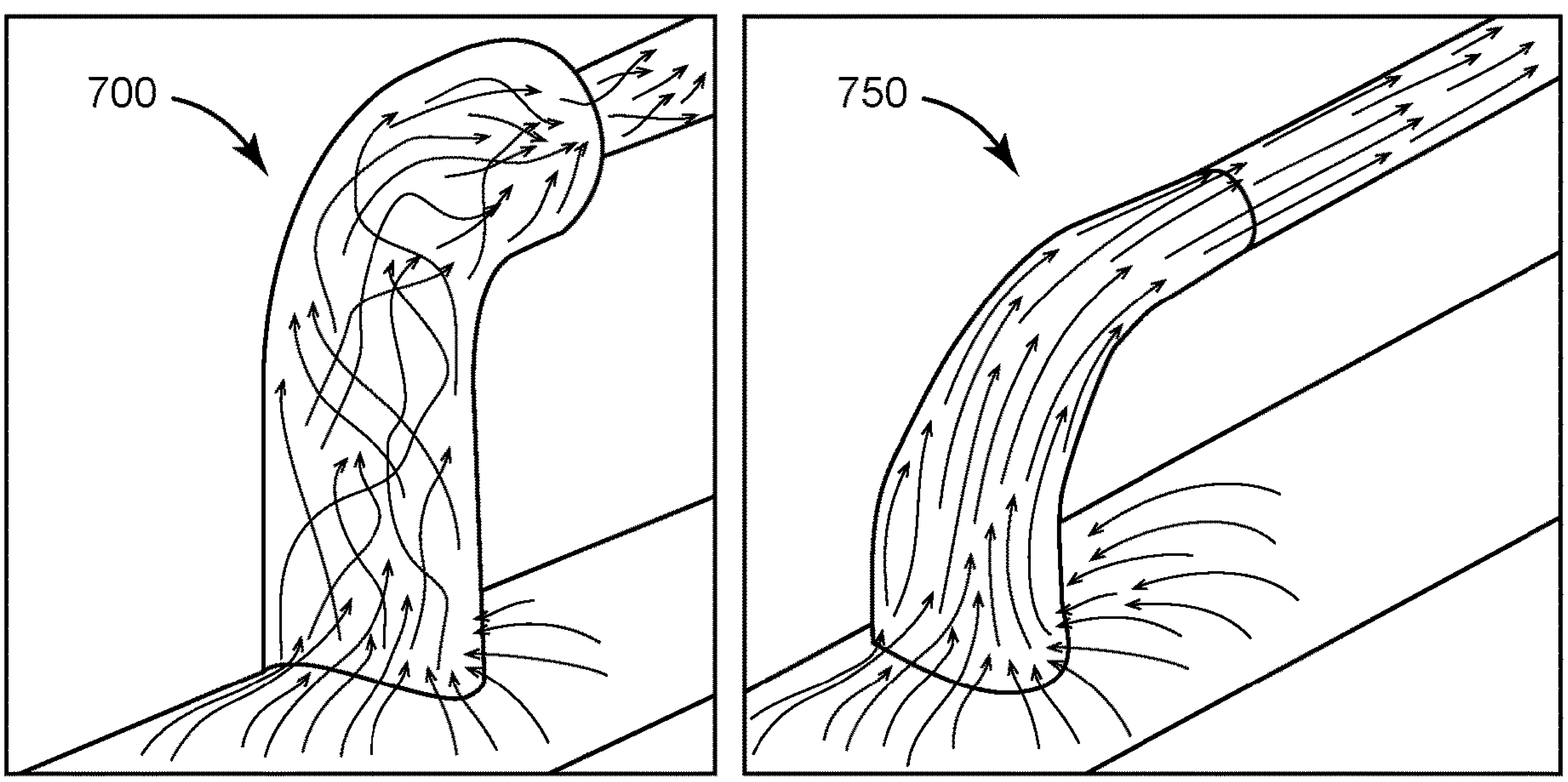

FIG. 7

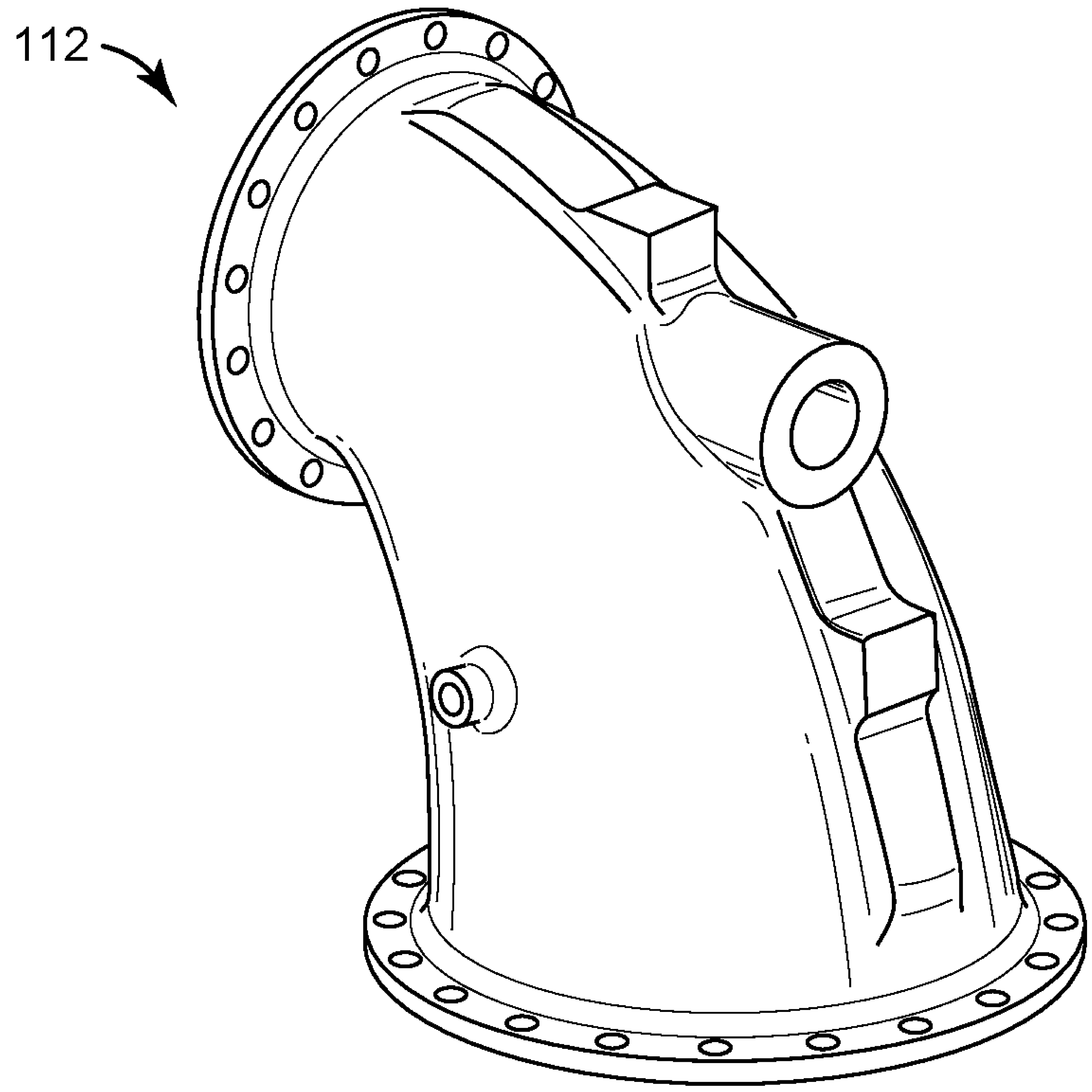

FIG. 8

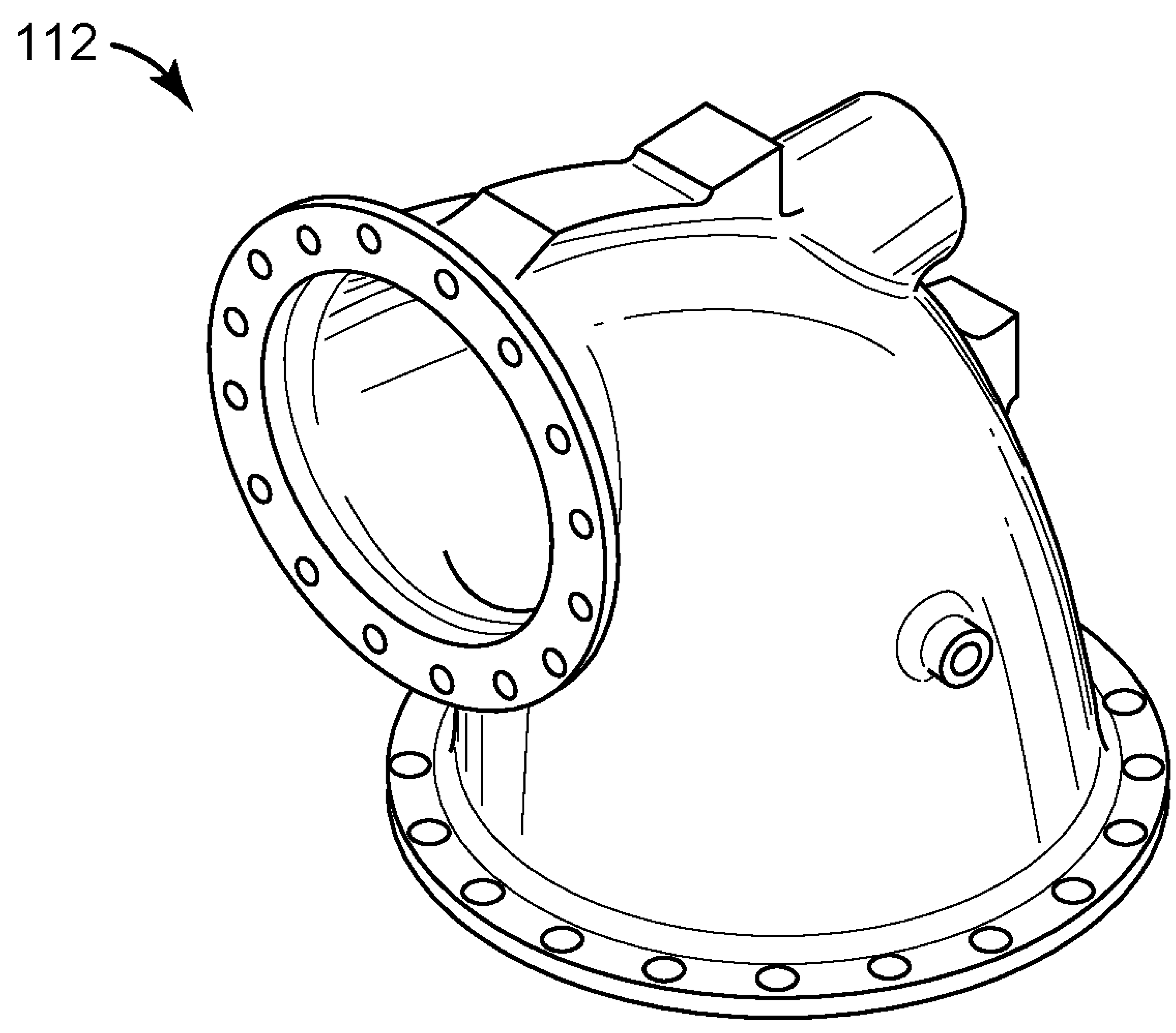

FIG. 9

CONVERGING SUCTION LINE FOR COMPRESSOR

CROSS-REFERENCE TO RELATED PATENT APPLICATION

This application claims the benefit of and priority to U.S. Provisional Patent Application No. 62/476,525 filed Mar. 24, 2017, the entire disclosure of which is incorporated by reference herein.

BACKGROUND

Buildings can include heating, ventilation and air conditioning (HVAC) systems to distribute or control air circulation.

SUMMARY

One implementation of the present disclosure is a compressor. The compressor includes an inlet and the inlet includes a flange and an impeller eye. The flange is connected to a suction line that transfers a refrigerant into the compressor via the impeller eye. The refrigerant flows into the compressor with an amount of swirl and an amount of pressure loss. The suction line includes a geometry that includes a constantly decreasing cross-sectional area in a direction towards the compressor. The geometry of the suction line is configured to reduce the amount of swirl and the pressure loss.

Another implementation of the present disclosure is a chiller assembly. The chiller assembly includes an evaporator configured to convert a refrigerant into a vapor. The evaporator includes an evaporator flange. The chiller assembly further includes a compressor including an inlet. The inlet includes a compressor flange and an impeller eye. The compressor flange is connected to a suction line. The suction line is attached to the evaporator via the evaporator flange and is configured to transfer the refrigerant into the compressor via the impeller eye. The refrigerant flows into the compressor with an amount of swirl and a pressure loss. The suction line includes a geometry that includes a constantly decreasing cross-sectional area in a direction towards the compressor. The geometry of the suction line is configured to reduce the amount of swirl and the pressure loss. The chiller assembly further includes a condenser attached to the compressor via a discharge line and configured to convert the refrigerant into a liquid.

Another implementation of the present disclosure is a method. The method includes providing a compressor including an inlet. The inlet includes a flange and an impeller eye. The flange is connected to a suction line that transfers a refrigerant into the compressor via the impeller eye. The refrigerant flows into the compressor with an amount of swirl and an amount of pressure loss. The suction line includes a geometry that includes a constantly decreasing cross-sectional area in a direction towards the compressor. The geometry of the suction line is configured to reduce the amount of swirl and the pressure loss.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a drawing of a chiller assembly.

FIG. **2** is a drawing of a compressor and a suction line associated with the chiller assembly of FIG. **1**.

FIG. **3** is a table including various examples of dimensional characteristics associated with the compressor inlet and the suction line of FIG. **2**.

FIG. **4** is a drawing of discrete locations where cross-sectional area of the suction line of FIG. **2** can be calculated.

FIG. **5** is a graph of cross-sectional area over the length of the suction line of FIG. **2** for two different compressor sizes.

FIG. **6** is a drawing of the suction line of FIG. **2** compared to a suction line with alternative dimensional characteristics.

FIG. **7** is an illustration of refrigerant flow exiting the suction line with alternative dimensional characteristics shown in FIG. **6** and the suction line of FIG. **2**.

FIG. **8** is a drawing of the suction line of FIG. **2**.

FIG. **9** is another drawing of the suction line of FIG. **2**.

DETAILED DESCRIPTION

Referring generally to the FIGURES, a chiller assembly with an optimized compressor suction line is shown. The suction line is configured to transfer refrigerant from an evaporator to a compressor as part of a chiller cycle associated with the chiller assembly. Flow conditioning devices such as pre-rotation vanes (PRVs), inlet guide vanes (IGVs), and other components are often used to provide a uniform flow of refrigerant into the compressor. However, the suction line can be fabricated as a metal casting with a decreasing cross-sectional area in order to provide a uniform flow at the compressor inlet without these additional components. The absence of these components allows for a more compact design of both the compressor and the suction line, thereby reducing cost and footprint of the chiller. In addition, the suction line can deliver reduced pressure loss that drives improved chiller efficiency. The converging suction line can be designed for use with a variety of compressor types and sizes as well as a variety of refrigerants.

Referring now to FIG. **1**, an example implementation of a chiller assembly **100** is shown. Chiller assembly **100** is shown to include a compressor **102** driven by a motor **104**, a condenser **106**, and an evaporator **108**. A refrigerant is circulated through chiller assembly **100** in a vapor compression cycle. Chiller assembly **100** can also include a control panel **114** to control operation of the vapor compression cycle within chiller assembly **100**.

Motor **104** can be powered by a variable speed drive (VSD) **110**. VSD **110** receives alternating current (AC) power with a particular fixed line voltage and fixed line frequency from an AC power source (not shown) and provides power having a variable voltage and frequency to motor **104**. Motor **104** can be any type of electric motor than can be powered by a VSD **110**. For example, motor **104** can be a high speed induction motor. Compressor **102** is driven by motor **104** to compress a refrigerant vapor received from evaporator **108** through a suction line **112**. Compressor **102** then delivers compressed refrigerant vapor to condenser **106** through a discharge line. Compressor **102** can be a centrifugal compressor, a screw compressor, a scroll compressor, a turbine compressor, or any other type of suitable compressor.

Evaporator **108** includes an internal tube bundle (not shown), a supply line **120** and a return line **122** for supplying and removing a process fluid to the internal tube bundle. The supply line **120** and the return line **122** can be in fluid communication with a component within a HVAC system (e.g., an air handler) via conduits that circulate the process fluid. The process fluid is a chilled liquid for cooling a building and can be, but is not limited to, water, ethylene glycol, calcium chloride brine, sodium chloride brine, or any other suitable liquid. Evaporator **108** is configured to lower the temperature of the process fluid as the process fluid passes through the tube bundle of evaporator **108** and exchanges heat with the refrigerant. Refrigerant vapor is formed in evaporator **108** by the refrigerant liquid delivered to the evaporator **108** exchanging heat with the process fluid and undergoing a phase change to refrigerant vapor.

Refrigerant vapor delivered by compressor **102** to condenser **106** transfers heat to a fluid. Refrigerant vapor condenses to refrigerant liquid in condenser **106** as a result of heat transfer with the fluid. The refrigerant liquid from condenser **106** flows through an expansion device and is returned to evaporator **108** to complete the refrigerant cycle of the chiller assembly **100**. Condenser **106** includes a supply line **116** and a return line **118** for circulating fluid between the condenser **106** and an external component of the HVAC system (e.g., a cooling tower). Fluid supplied to the condenser **106** via return line **118** exchanges heat with the refrigerant in the condenser **106** and is removed from the condenser **106** via supply line **116** to complete the cycle. The fluid circulating through the condenser **106** can be water or any other suitable liquid.

Referring now to FIG. **2**, various dimensional characteristics associated with suction line **112** and compressor **102** are shown. An inlet to compressor **102** includes a flange and an impeller eye. The flange can be configured to attach compressor **102** to suction line **112**. The impeller eye can be configured to accept refrigerant into compressor **102** via suction line **112**. As shown in FIG. **2**, the impeller eye can be defined by a diameter **210** and the compressor flange can be defined by a diameter **208**. The compressor inlet is defined by compressor inlet length **212**. Compressor inlet angle **214** can be defined as the angle from the top of the impeller eye to the top of the compressor flange relative to the horizontal direction as shown in FIG. **2**.

Suction line **112** can be attached to evaporator **108** via an evaporator flange. The evaporator flange can be defined by a diameter **206** that is greater than compressor flange diameter **208**. A height **204** of suction line **112** can be defined from the evaporator flange to the center of the compressor flange as shown in FIG. **2**. An axial length **202** of suction line **112** can be defined from the center of the evaporator flange to the impeller eye. As can be inferred from FIG. **2**, refrigerant flowing through suction line **112** makes approximately a 90 degree turn.

Referring now to FIG. **3**, a table **300** including example values of the dimensional characteristics defined in FIG. **2** is shown. As mentioned above, the converging suction line design can be applied to a variety of chillers that use a variety of different compressors and a variety of refrigerant types. Table **300** lists dimensional characteristics associated with compressor capacities of 300, 450, 520, 630, 750, 880, 1000, and 1200 tons of refrigeration (TR). As a reference, typical operating conditions of chiller assembly **100** associated with the data in table **300** include a suction pressure of about 8.8 psia, a suction temperature of about 43.1° F., a suction density of about

$$0.22\ \frac{\text{lbm}}{\text{ft}^3},$$

and a low pressure remgerant (e.g., R1233zd). Dimensional characteristics shown in table **300** include suction line axial length **202**, suction line height **204**, evaporator flange diameter **206**, compressor flange diameter **208**, impeller eye diameter **210**, compressor inlet axial length **212**, and compressor inlet angle **214**. Also shown in table **300** is a ratio **216** of suction line inlet diameter (i.e., evaporator flange diameter **206**) to suction line outlet diameter (i.e., compressor flange diameter **208**). It should be noted that the numbers shown in table **300** are examples and slight variations are contemplated within the scope of the present disclosure. The general relationships and design principles that can be inferred from table **300** result in a high performance suction line **112**.

The dimensional characteristics shown in table **300** highlight key features of the design of suction line **112**. For example, it can be inferred from table **300** that, depending on compressor size, compressor inlet angle **214** should be between 4 and 10 degrees. In addition, it can be inferred from table **300** that ratio **216** of evaporator flange diameter to compressor flange diameter should be between 1.4 and 1.8. Further, it can be inferred that a ratio of external suction line height to length

$$\left(\text{i.e., external height to length} = \frac{\text{height } 204}{\text{length } 202 - \text{inlet length } 212}\right)$$

should be between 1.1 and 1.3.

Referring now to FIG. **4**, a drawing of discrete locations where cross-sectional area of suction line **112** can be calculated is shown. The arrow indicates the direction of refrigerant flow through suction line **112** from evaporator outlet **206** to compressor inlet **210**. Each of the ten horizontal lines shown represents a cross section of suction line **112**. It can be inferred from FIG. **4** that, in a direction towards the compressor, the cross-sectional area of suction line **112** decreases. For example, starting at the evaporator end, each successive horizontal line has a shorter length. Given that the cross-sectional area within suction line **112** can be defined as $A=\pi r^2$, a smaller diameter (and radius) corresponds to a smaller cross-sectional area. This concept of a decreasing cross-sectional area is consistent with and expands upon the dimensional characteristics and relationships shown in table **300**.

Referring now to FIG. **5**, an example graph **500** of cross-sectional area of suction line **112** for two different compressor sizes is shown. Line **512** shows the cross-sectional area at ten evenly-spaced points (e.g., the locations shown in FIG. **4**) of suction line **112** designed for a compressor size of 880TR. It can be seen from line **512** that, at each successive point, the cross-sectional area of suction line **112** decreases in a direction towards the compressor. Line **502** depicts a linear fit applied to the data points associated with line **512**. Line **502** can be used as a reference to infer from graph **500** that the cross-sectional area of suction line **112** not only decreases, but it also decreases non-linearly (e.g., non-linear convergence). In a similar fashion, line **514** depicts the cross-sectional area of suction line **112** at ten evenly-spaced points and optimized for a compressor size of 300TR. Line **504** depicts a linear fit of the data points associated with line **514** and can be used as a reference to again infer that the cross-sectional area of suction line **112** decreases in a non-linear fashion.

Referring now to FIG. **6**, a drawing **600** of suction line **112** compared to a suction line **612** with alternative dimensional characteristics is shown. Drawing **600** shows suction line **112** and suction line **612** aligned at the start of the compressor inlet. A compressor inlet associated with suction lines **112** and **612**, respectively, is represented by length **602**. Suction lines **112** and **612** themselves are represented by length **604**. Suction line **612** is shown to have a constant or relatively constant cross-sectional area. As a result, the flow of refrigerant entering a compressor via suction line **612** has a high amount of swirl, a large amount of pressure loss, and a high degree of non-uniformity (e.g., asymmetrical, flow velocity in some directions greater than flow velocity in other directions). In addition, the flow of refrigerant through suction line **612** may separate at the inner radius, thus forming a double counter-rotating vortex. As a result, additional components such as pre-rotation vanes (PRVs), inlet guide vanes (IGVs), and other flow conditioning devices are often used. The decreasing cross-sectional area and other dimensional characteristics of suction line **112** can be optimized for a variety of compressor sizes in order to decrease the amount of swirl, the amount of pressure loss, and provide more uniform flow of refrigerant into compressor **102**. As a result, the overall size of both compressor **102** and suction line **112** can be reduced since flow conditioning devices and other components are not needed.

Referring now to FIG. **7**, an illustration **700** of refrigerant flow exiting suction line **612** and an illustration **750** of refrigerant flow exiting suction line **112** are shown. As shown in illustration **700**, the flow of refrigerant exiting suction line **612** (e.g., a "long radius elbow") is much more non-uniform (e.g., asymmetrical) and has a higher amount of swirl than shown in illustration **750** for suction line **112**. It can also be seen from illustrations **700** and **750** that that flow of refrigerant exiting suction line **612** has a much higher amount of radial separation when compared to the flow exiting suction line **112**. Suction line **112** can deliver a reduction in pressure loss of about 35% and a reduction in swirl velocity of about 26% in some examples. A bell-shaped mouth or other type of complex design is often used at the compressor inlet with suction line **612**, however such a complex design may not be needed as a result of the optimized design of suction line **112**. Due to the reduction in pressure loss and other benefits associated with the design of suction line **112**, a benefit to the overall chiller cycle executed by chiller assembly **100** can be seen without any loss in compressor performance.

Referring now to FIG. **8**, a perspective view drawing of suction line **112** is shown. Suction line **112** can be fabricated as a metal casting and can include a sight glass port and a pressure probe port. The sight glass port can be configured to allow operators, technicians, and other personnel to visually see refrigerant flowing through suction line **112**. The pressure probe port can be configured to allow operators, technicians, and other personnel to measure pressure of refrigerant flowing through suction line **112**. FIG. **9** shows a similar perspective view of suction line **112** from a different angle. Dimensional characteristics associated with suction line **112** such as decreasing cross-sectional can be seen in FIG. **8** and FIG. **9**.

The construction and arrangement of the systems and methods as shown in the various exemplary embodiments are illustrative only. Although only example embodiments have been described in detail in this disclosure, many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.). For example, the position of elements can be reversed or otherwise varied and the nature or number of discrete elements or positions can be altered or varied. Accordingly, such modifications are intended to be included within the scope of the present disclosure. The order or sequence of any process or method steps can be varied or re-sequenced according to alternative embodiments. Other substitutions, modifications, changes, and omissions can be made in the design, operating conditions and arrangement of the examples provided without departing from the scope of the present disclosure.

What is claimed is:

1. A compressor, comprising:

an inlet including a flange and an impeller eye, the flange connected to a suction line that transfers a refrigerant into the compressor via the impeller eye;

wherein the suction line has a geometry that includes a constantly decreasing cross-sectional area throughout a length of the suction line in a direction towards the compressor, and wherein the constantly decreasing cross-sectional area decreases at a non-linear rate.

2. The compressor of claim **1**, wherein the constantly decreasing cross-sectional area decreases at the non-linear rate such that the cross-section area decreases in the direction towards the compressor in a non-uniform manner.

3. The compressor of claim **1**, wherein the compressor operates as part of a chiller assembly, the chiller assembly including an evaporator configured to convert the refrigerant into vapor, a motor configured to drive the compressor, and a condenser configured to convert the vapor into a liquid.

4. The compressor of claim **3**, wherein the suction line is connected to the evaporator via an evaporator flange, and wherein the refrigerant is transferred from the evaporator and through the suction line to the compressor.

5. The compressor of claim **1**, wherein a compressor inlet angle ranges from 4-10 degrees, the compressor inlet angle defined from a top edge of the impeller eye to a top edge of the flange.

6. The compressor of claim **4**, wherein a ratio of diameter of the evaporator flange to diameter of the compressor flange ranges from 1.4 to 1.8.

7. The compressor of claim **1**, wherein an external height to length ratio of the suction line ranges from 1.1 to 1.3.

8. The compressor of claim **1**, wherein the suction line includes a pressure probe port configured to enable pressure measurements of the refrigerant.

9. The compressor of claim **1**, wherein the suction line includes a sight glass port configured to enable sight of the refrigerant.

10. The compressor of claim **1**, wherein the refrigerant completes a turn of approximately 90 degrees when flowing through the suction line and into the compressor.

11. The compressor of claim **4**, wherein the refrigerant completes a turn of approximately 90 degrees when flowing out of the evaporator, through the suction line, and into the compressor.

12. The compressor of claim **1**, wherein the refrigerant flows into the compressor with an amount of radial separation.

13. The compressor of claim **1**, wherein the refrigerant flows into the compressor with an amount of non-uniformity.

14. The compressor of claim **12**, wherein the geometry of the suction line is configured to reduce the amount of radial separation.

15. The compressor of claim **13**, wherein the geometry of the suction line is configured to reduce the amount of non-uniformity.

16. A method, comprising:

providing a compressor, the compressor including an inlet including a flange and an impeller eye, the flange connected to a suction line that transfers a refrigerant into the compressor via the impeller eye;

wherein the suction line has a geometry that includes a constantly decreasing cross-sectional area throughout a length of the suction line in a direction towards the compressor, and wherein the constantly decreasing cross-sectional area decreases at a non-linear rate.

17. The method of claim **16**, comprising providing the compressor without pre-rotation vanes or guide vanes.

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